Cushman No. 1 Hydroelectric Power Plant, Spillway
Spanning the North Fork of the Skokomish River,
approximately 5 miles west of Hood Canal
Hoodsport Vicinity
Mason County
Washington

HAER No. WA-26-A

HAER
WASH,
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1-A-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
Western Regional Office
National Park Service
U. S. Department of the Interior
San Francisco, California 94102

HAER
WASH,
23-HOPO.V,
1-A-

HISTORIC AMERICAN ENGINEERING RECORD

Cushman No. 1 Hydroelectric Power Plant, Spillway

HAER No. WA-26-A

Location:	Power Plant - Spanning the North Fork of the Skokomish River, approximately 5 miles west of Hood Canal and the town of Hoodsport. Spillway - one-quarter mile south of the dam. Hoodsport vicinity, Mason County, Washington
	UTM: 483150 Easting, 5251400 Northing; T22N, R4W, Sections 5 and 8 Quad: Potlatch, Washington
Dates of Construction:	1926-1929. Altered several times (see text of this report for dates and description of alteration)
Engineers:	J. L. Stannard - Chief Engineer B. E. Torpen - Design and Construction A. F. Darland - Electrical Engineer N. L. Taylor - Surveyor J. V. Gongwer - Structural Engineer
Geologist:	I. A. Williams Consulting Geologist Oregon Bureau of Mines and Geology
Present Owner:	City of Tacoma Light Division Department of Public Utilities P.O. Box 11007 Tacoma, Washington 98411
Present Use:	Reservoir spillway; to be demolished and reconstructed 1990
Significance:	The Cushman No. 1 Hydroelectric Power Plant is a significant example of medium head hydroelectric technology in the west from the 1920s. Located in steep, inaccessible terrain prone to flooding, the plant construction was a significant engineering feat and used a revolutionary design for the time, a constant angle concrete arch dam, for the steep, narrow gorge in which it is located. When completed in 1925, the dam formed a lake 9.6 miles long, covering 4,000 acrea, which was the largest reservoir in the Pacific Northwest and the tenth largest in the United States.

The spillway is unusual for its converging chute design. It also is notable for hydrologic patterns (standing waves) that develop during spills and which result from the converging design of the structure.

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Under the direction of the City of Tacoma, Department of Public Utilities, Light Division

Date: September 1989

LAYOUT OF THE SITE

The Cushman No. 1 Hydroelectric Power Plant is located on the North Fork of the Skokomish River, approximately 37 air miles (approximately 70 road miles) northwest of Tacoma, and five miles west of Hood Canal and the town of Hoodsport in Mason County, Washington [City of Tacoma, 1977; Soderbsrg, 1986]. The north fork of Skokomish River flows into Lake Cushman at river-mile (RM) 28 and the dam is located at RM 19.6. The reservoir is roughly an 'L' shape, with one leg of the 'L' oriented north/south and the other oriented northwest/southeast. The Cushman No. 1 Dam (Lake Cushman Dam) is locatsd in a steep, narrow gorge at the southern end of the reservoir on the southeast rim. Figure 1 of this report illustrates the orientation and general layout of the Cushman project.

The spillway is located in a saddle about one-quarter mile south of the Cushman No. 1 Dam along the southeast rim of the reservoir (see Figure 2 of this report). The spillway is straight in plan, discharging into a chute 900 feet long to Deer Meadow Creek, a drop of 103 feet in elevation (Harza Engineering Company, 1973; also, see HAER Photographs Number WA-26-A-1 through WA-26-A-5 and WA-26-A-21). The spillway is an ungatsd structure; however, timber flashboards, three feet tall, are installed to increase storage in the reservoir during the months of March to September. Access to the spillway is by an 8-foot-wide roadway over the crest of the dam. The spillway, as well as the adjoining short earth dikes flanking either side of the structure, is located on glacial outwash. A concrste cutoff wall sxtends through the earth dikes and under the spillway. This cutoff wall reportedly does not extend to rock, but extends to a depth of approximately 30 feet; the material below the cutoff wall is of a composition (flowing or "quick" sand) that prohibited deepening of the wall to rock during construction (Harza Engineering Company, 1973). Underdrains six inches in diameter and located beneath the spillway chute slabs, direct the groundwater into collection drains ranging in diameter from six inches at the chute crest to ten inches at the downstream end. The collection drains discharge on the outside of the retaining walls at the downstream end of the spillway (in the vicinity of Deer Meadow Creek). (See HAER Photographa No. WA-26-A-18 through WA-26-A-24 for engineering details of the spillway structure.)

Construction, Alteration, Significant Changes Over Time

Initially, the Cushman site was investigated in 1912 by the Skokomish Power Company and the city of Seattle as a potential location for a hydroelectric project [City of Tacoma, 1977]. It was not until 1917 that officials from the city of Tacoma recognized the need for additional electric energy to meet the city's eacalating power load demands and studied five major sites for future development, including the Cushman site, which was determined to be best suited for the city's needa. In 1919, voters approved a $300,000 bond issue for the purchase of land and water rights for the two-phase Cushman project, to include the upper (Cushman No. 1) and lower (Cushman No. 2) dams [City of Tacoma, 1977; Soderberg, 1986].

Following exploratory drilling and surveys at the Cushman site, the Cushman Power Project Engineering Division was organized in 1923 to supervise design and construction [City of Tacoma, 1977]. A revolutionary design for the time, a constant angle concrete arch dam, was specified for the steep, narrow gorge in which the Cushman No. 1 Dam would be located. The first major contract was awarded March 31, 1924, and contractors began work on the excavation of the powerhouae foundation. However, frequent floods delayed work on the powerhouae, and actual construction did not commence until June 1925 [Soderberg, 1986]. When completed on Thanksgiving Day in 1925, the 275-foot-high dam formed a lake 9.6 miles long, covering 4,000 acres. Lake Cushman became the largest reservoir in the Pacific Northweat and the tenth largest in the United States. The project was energized on March 21, 1926.

During construction of the main features of the project (1924-1926), borings were made in the proposed structure and the character of materials that would be encountered during construction [Stannard, 1927]. A heavy layer of gravel, fine sand mixed with clay, and pure sand were found in depths of over 60 feet before hard, impervious material was encountered [Stannard, 1927]. Several drawings from the Tacoma Light Division indicate the spillway originally was proposed to be located on bedrock nearer to the dam by approximately 200 feet than the location of the final structure, but the final decision was to build the crest structure on glacial outwash further to the south, with a seepage cutoff wall extending to impervious material.

In the fall of 1926, a contract was let for construction of the spillway. Work commenced shortly thereafter, but was delayed before much progress was made by onset of fall rains. Construction activities included grading, excavation of the cutoff trench, installation of the planking on the downstream side, pouring of the apron, and construction of the log crib dam (see HAER Photographs No. WA-26-A-6 through WA-26-A-9). During construction, it was necessary to open the Johnson valve at the base of the dam to lower the reservoir water elevation below the bottom elevation of the spillway cutoff trench to prevent flooding of the trench [Stannard, 1927]. After completion of the concrete cutoff wall, the Johnson valve was closed and the reservoir level allowed to rise. The spillway was completed in April 1927, and in the early part of July, the reservoir elevation had risen to nearly the crest of the spillway [Stannard, 1927].

Initially, the spillway was a weir (a small dam) with a trapezoidal cross-section [Rydell, et al., 1928]. The base was 200 feet wide and the sides were built on a slope of 1.5:1, varying from 9 feet to 7 feet in height. The upstream face was 20 feet long and inclined toward the reservoir (away from the crest) at a slope of 25 percent. The crest was 20 feet long (in the direction of flow) and flat. The downstream face was 40 feet long and inclined away from the crest (away from the reservoir) at a slope of 17.5 percent. Approximately 450 feet downstream (south of the downstream extent of concrete, a log crib dam was constructed. During overflow or flood, water would flow from the reservoir, over the crest of the weir, across a graded, dirt "channel," and over the log crib dam into the forest, eventually flowing to Deer MeAdow Creek, located in a canyon further downstream (see HAER Photograph No. WA-26-A-10).

In December 1927, J. L. Stannard, Chief Engineer for the Cushman Project, wrote that "Water has, since that time [completion of the spillway], been over the spillway and the whole structure proven as to its stability and water tightness" [Stannard, 1927). Although the structure had demonstrated its effectiveness, following heavy rains in the fall of 1927 and spring of 1928, the decision was made to extend the weir in the downstream direction with a concrete-lined channel or chute. The purpose of the channel was to provide a meaNs of carrying away the overflow water from the existing weir to a creek canyon (Deer Meadow Creek), a distance of approximately 900 feet downstream [Rydell, et al., 1928]. The type of channel chosen was a concrete chute, rectangular in cross section, and wider at the upstream than the downstream end. It would follow approximately the slope of the ground, which varied from 3 percent near the upper end (at the reservoir) to 25 percent near the lower end (At the inlet to Deer Meadow Creek) [Rydell, et al., 1928]. No falls or baffles would be used to slow the velocity of water through the spillway; water would instead be allowed to flow freely and discharge at a high velocity into the creek canyon. At the time, it was believed that the discharge would not cause any damage to the creek canyon or the spillway structure, because "the canyon slopes sharply away from the end of the flume and is eroded to rock"

[Rydell, et al., 1928]. Construction of a cutoff wall into rock or hardpan at the end of the chute also was proposed to protect the spillway from any backwash and potential erosion during discharge.

Calculations were made to determine the capacity of the channel. It was determined that the spillway would be designed to accommodate the maximum discharge under flood conditions, which had previously been found to be 14,100 cubic feet per second (cfs) [Rydell, et al., 1928]. As a safety factor, the quantity of 18,000 cfs was used in designing the channel, an increase of 28% over the calculated flow. Subsequent to completion of the spillway, it was found that the capacity of the structure approximated the flow that would be experienced under 100-year flood conditions. A minimum freeboard of 1.5 feet would be allowed on the sides of the channel to accommodate any wave action that might occur along the walls during discharge [Rydell, et al., 1928].

In 1928, L. E. Rydell, O. A. Abelson and V. R. Rathbim, in a report entitled "Investigation of Flow in Spillway, Cushman Power Plant No. 1, April 1928," described the design of the proposed spillway as follows:

> The proposed channel section of the spillway begins at the end of the 27.5 percent slope, changing through a vertical curve to a 3 percent slope, and then in sequence to 7.5 percent, 25 percent, and 17.6 percent slopes, in a distance of 820 feet. In order to keep the depth of water approximately uniform in the channel, the width of channel is decreased from 200 feet at the upper end to 65 feet at the lower end, somewhat funnel-shaped in plan, with the sides at the upper end gradually converging from the 200 foot width at the spillway weir. The sides are warped from the 1.5:1 slope at the end of the weir section, to vertical at a point 100 feet ahead, making the channel rectangular in section with walls 6 feet high. The axis of the channel section intersects the axis of the weir section at an angle of 8 degrees 08 feet; and the direction of flow is changed in the first 100-foot section while the water velocity is still low.
>
> It will be noted... that for a flow of 18,000 c.f.s., the water reaches a maximum velocity of 68 feet per second at the end of the chute. This velocity seems high, but a study of the topography at the site will show that the high velocity can do no harm to either the chute itself or to terrain below the end of the concrete channel as the water discharges almost directly into the head of a steep creek canyon. The bottom of this canyon is eroded to rock or hardpan; its slope is sufficient to take care of any quantity of water that may be flowing from the chute without causing any piling up of water.

Initial work to complete this addition to the spillway commenced in the fall of 1928 and construction proceeded through the spring of 1929. Construction included excavation, rolling and finishing of the sub-grade, laying drains, placing steel for the first slabs, pouring the wall base, pouring the slsbs, and completion of the walls and slabs. Construction activities and progress is well-documented in historic photographs in the city of Tacoma, Light Division archives (see HAER Photographs No. WA-26-A-11 snd WA-26-A-12). Construction was completed in the fall of 1929.

When completed, the spillway did not follow precisely the description written by L. E. Rydell, et al., in 1928. For instance, the walls on the completed spillway were seven feet high, not six feet as described by Rydell. The final design transitioned from a 27.5 percent slope immediately downstream of the spillway crest, through 2.96 percent, 8.89 percent, and 19.13 percent slopes to a 37.20 percent slope on the downstream end. The spillway wss s total of 900 feet in length, including the original weir, 200 feet wide at the crest, and 80 feet wide at the downstream end. (See HAER Photograph No. WA-26-A-21 to review the plan and section of the final spillway design.)

Additional elements proposed to be a part of the originsl spillway included a trestle bridge, fish screens, and flashboards. Automobile access to the spillway initially was provided by wooden auto ramps on either side of the crest. The ramps extended from the top of the retaining walls to the base of spillway crest, allowing vehicles to descend seven feet from the top of the walls and drive across the structure. (A photograph, dated April 1931 and contained in the Tacoma archives, shows the ramps in place during overflow of the spillway.) A design for the trestle bridge, which would improve crossing the spillway, is included in an unsigned city of Tacoma, Light Division drawing dated October 1931. This bridge was installed across the crest of the spillway shortly following completion of the chute and first sppears in historic photographs in 1932 (see HAER Photographs Number WA-26-A-14 and WA-26-A-22). The unsigned 1931 drawing also includes fish screens, composed of 1 by 6-foot wooden sections ten feet in height, which also were intended to span the crest of the spillway. However, installation of the fish screens is not known to have occurred and is not recorded in any historic photographs in the archives of the Light Division, city of Tacoma.

The design of the flashboards, the purchase of which is to allow the reservoir level to rise above the crest of the spillway, is included in a drawing of the weir by the Light Division, city of Tacoma, dated September 1926, and in a subsequent drawing of the spillway chute, dated 1927 (see HAER Photograph No. WA-26-A-19). Sockets for the flashboards were installed within the headworks of the original weir, and reference is made in the flood records of the Light Division to the flashboards being installed and activated during 1934. However, it is uncertain when the flashboards first were installed.

The flashbosrds were designed to trip with overtopping of approximately three feet of water. Cables were installed which allowed the first three boards on the eastern side to be pulled out mechsnically (by truck). A safety pin also was installed to keep unauthorized people from tampering with the system. The actuation system allowed the first flashboard to be removed by first removing the safety pin by hand and then pulling the cable tied to the east spillway abutment slope. The cable thus pulled facilitated extraction of the first flashboard and the rest of the flashboards were supported in such a way that they would trip in a "domino" fashion from east to west across the spillway crest. The same actuation system is still used today.

During the early 1930s, the spillway remained relatively unchanged, with the exception of installation of the trestle bridge and the flashboards. Heavy flooding and consequent discharges through the spillway during 1930 and 1931, however, resulted in erosion at the base of the chute (Deer Meadow Creek) and along the outside of the eastern retaining wall. Additional construction, therefore, occurred in 1934 to repair and improve the structure.

The original cutoff wall at the end of the spillway did not tie in well with the underlying rock. Erosion caused by the flooding that occurred in the early 1930s; therefore , necessitated additional construction at the downstream end of the chute. The plunge pool was dewatered, concrete was poured from the base of the spillway to the bottom of the pool where the erosion had occurred, thus extending the cutoff wall, and a retaining wall was constructed from the base of the spillway east for several feet. At the same time, concrete was poured in a washout along the eastern retaining wall.

Flooding during 1955 and 1956 resulted in a need for additional remedial work on the spillway. An inspection on October 24, 1956, showed that the side drains along the outside of the spillway were blocked with roots [City of Tacoma, 1955-1956]. Blockage of the drains had caused several slabs on the spillway chute to lift during flood conditions. The drains, therefore, were cleaned with a sewer cleaner, which necessitated digging holes approximately nine feet deep and large enough to work in along the outside of the spillway. Following the cleaning, it was planned to leave stand pipes of large tile over the points where the drains were opened, with covers to be placed over the tile; this would leave access points for future inspections to determine if the drains were functioning properly [City of Tacoma, 1955-1956]. In addition, all trees and brush to a minimum of 100 feet from the spillway was cut back and stumps were poisoned to allow ease of maintenance in the future. With the release of pressure, all slabs except the sixth one down on the west side went back into place; this sixth slab remains uplifted by approximately three inches today.

In 1981, vehicle access was improved by construction of concrete ramps on either side of the spillway, which replaced the trestle bridge. A portion of the retaining wall was removed on either side of the chute on the crest, soils were excavated, and concrete walls and ramps were poured (see HAER Photograph No. WA-26-A-24). At the same time, the trestle bridge was removed and the flashboard sockets were moved upstream from their original position.

The next major alteration of the spillway will occur in 1989, with its demolition and replacement with an orifice radial gated spillway structure (see Figure 3 of this report). This demolition is necessitated by a Federal Energy Regulatory Commission (FERC) mandate that requires the dam and spillway to accommodate the Probable Maximum Flood (PMF).

Prior to 1972, operating procedures involved maintaining the reservoir at or near elevation (El) 738 during the summer with a 10- to 20-foot drawdown in winter to store the winter rainfall and spring runoffs. In 1972, the FERC formally mandated a 15-foot winter drawdown of the reservoir to accommodate one-half of the PMF without overtopping the dam. In 1982, changes in the reservoir seasonal operations again were ordered by FERC in an attempt to maximize the ability of the project to pass the full PMF. It was determined that the project, in its current configuration, was not able to pass the PMF without overtopping the dam. Hence, special operating procedures were adopted in 1982, resulting in winter drawdown ranging from 57 to 75 feet (El 663 to El 681), and the Tacoma Light Division began investigation of alternative control methods that would control the PMF and allow raising of winter reservoir levels. Following issuance of the Draft and Final Environmental Impact Statement on the alternative control methods, it was determined that demolition of the existing spillway structure and its replacement with an orifice radial gated spill structure would best satisfy the FERC-mandated capacity requirements.

In November 1989, demolition of the existing spillway will begin to allow its replacement with a new orifice radial gated spillway. The new spillway will retain the existing concrete poured in the plunge pool of Deer Meadow Creek and use the broken remains of the existing spillway walls and slabs to line the sides of the plunge pool. From the reservoir side, the new spillway will attempt to blend with the old by copying the architectural detailing of the parapet wall on the dam. This attention to detail will make the new spillway appear as a twin to the dam on the reservoir.

Individuals Associated With the Site

Construction of the Cushman Project was spearheaded by Homer T. Bone, an attorney for the city of Tacoma and an early promoter of public utilities in the Northwest. Bone was elected to the United States Senate in 1932 [City of Tacoma, 1977a] The proposed construction was described as a "major victory for advocates of public power in the 1920s" and resulted in a lengthy legal battle between the city of Tacoma's Light Division and the Simpson Timber Company over equitable compensation for the company's timberlands that were flooded by the endeavor [City of Tacoma, 1977a].

Key individuals involved in construction of the project included:

J. L. Stannard, Chief Engineer
B. E. Torpen, Design and Construction
A. F. Darland, Electrical Engineer
N. L. Taylor, Surveyor
J. V. Gongwer, Structural Engineer
I. A. Williams, Consulting Geologist, Oregon Bureau of Mines and Geology

Technology Used in Construction and Operation of the Site

Throughout construction, transportation of equipment and supplies was facilitated by the existence of a logging railroad and a road within one-half-mile of the site [Soderberg, 1986]. The logging railroad originated some distance to the west of the Cushman Project construction site, and travelled along what is now U. S. Forest Service Road 2340, crossing the South Fork of the Skokomish River on a steel bridge and ending on the west side of Deer Meadow, in the vicinity of McTaggert Creek. The railroad terminated at this juncture due to the steep grades in the vicinity; however, it is possible that a spur track provided access to the spillway construction site.

Equipment and cement were shipped by barge through Hood Canal to the logging road terminal at Hoodsport, where the materials were transferred to trucks for hauling to the site. A large gravel bar located directly above the dam supplied the sand and gravel for the entire project [Soderberg, 1986]. A mixer was constructed on site to provide concrete for the slabs and retaining walls of the spillway structure.

Use and Operation of Structure

The spillway is used to accommodate reservoir overflow and originally was designed to accommodate maximum flood flows and a 28% safety factor. Subsequent to completion of the spillway in 1929, it was found that the capacity of the structure approximated the flow that would be experienced under 100-year flood conditions. Should a flood situation occur, the spillway would be used to release water from the reservoir to avoid overtopping the dam. Spills at the spillway have been infrequent, with approximately 23 occurrences between completion in 1927 and 1989.

Significant Events or Figures in History of the Site

The largest recorded spill at the spillway was in December 1933. This spill measured 4.8 feet at the spillway crest and had a discharge of approximately 6,500 cfs.

Additional Background and Contextual Information

The costs of construction (in 1927 dollars) for the Cushman No. 1 Hydroelectric Power Plant (including the spillway structure) were recorded by J. L. Stannard in "City of Tacoma, Cushman Project, Unit No. 1, Final Report of Construction and Cost of Plant" as the following:

Intangible Capital	$ 68,856.93
Lands	352,138.89
Dams, Tunnels, Power House	3,395,770.20
Transmission Lines, Telephone System	1,006,364.32
Substation	427,114.36
Engineering Superintendence, etc.	226,784.34
TOTAL	$5,477,029.04
Interest on Construction Dollars	422,092.65
TOTAL CONSTRUCTION (INCLUDING INTEREST)	$5,899,121.69

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City of Tacoma, Department of Public Utilities, 1977a. Application for Relicensing to the Federal Energy Regulatory Commission (FERC) for the Cushman Project, FERC No. 460, Mason County, Washington. Exhibit V.

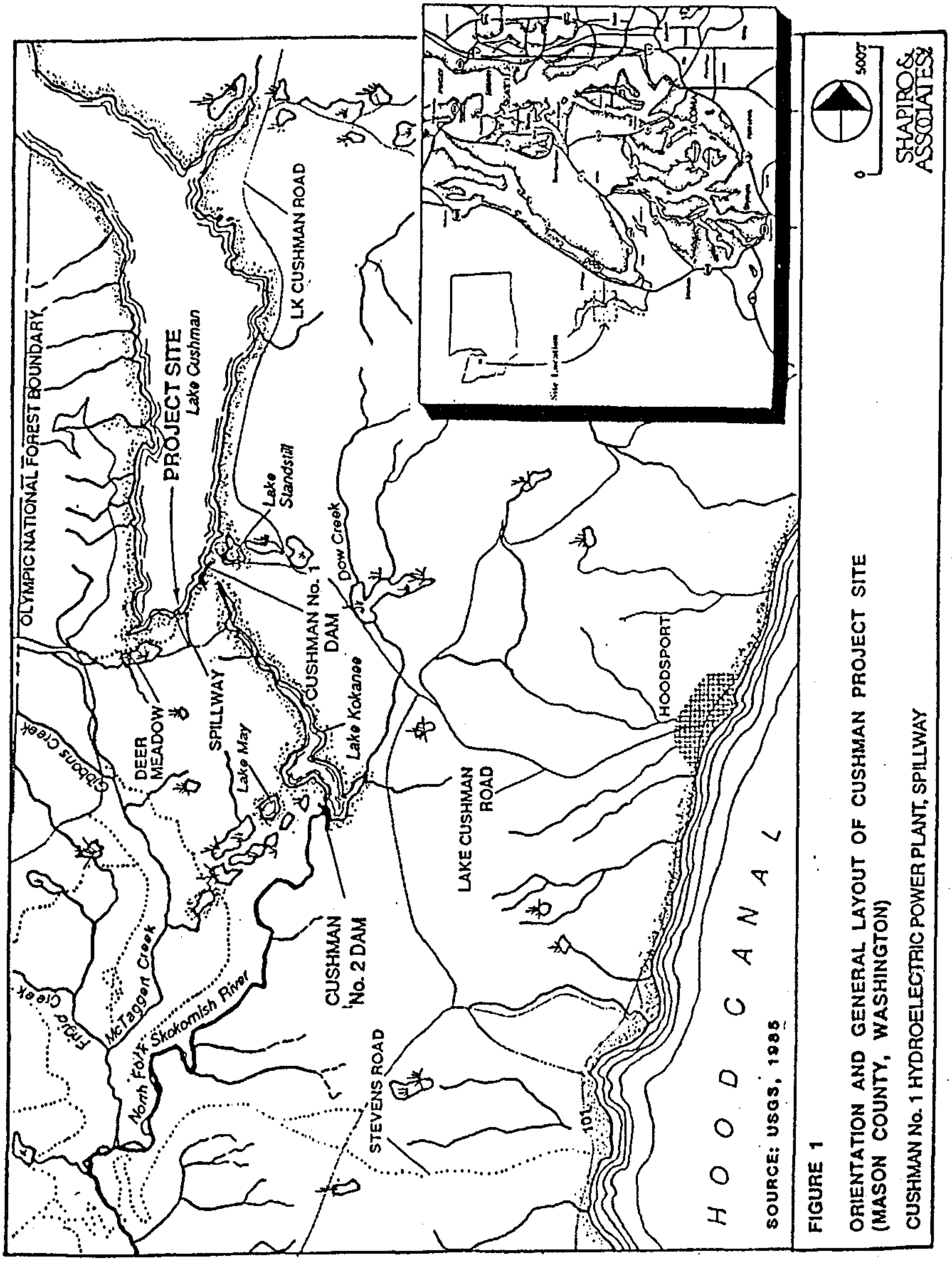

FIGURE 1

ORIENTATION AND GENERAL LAYOUT OF CUSHMAN PROJECT SITE (MASON COUNTY, WASHINGTON)

CUSHMAN No. 1 HYDROELECTRIC POWER PLANT, SPILLWAY

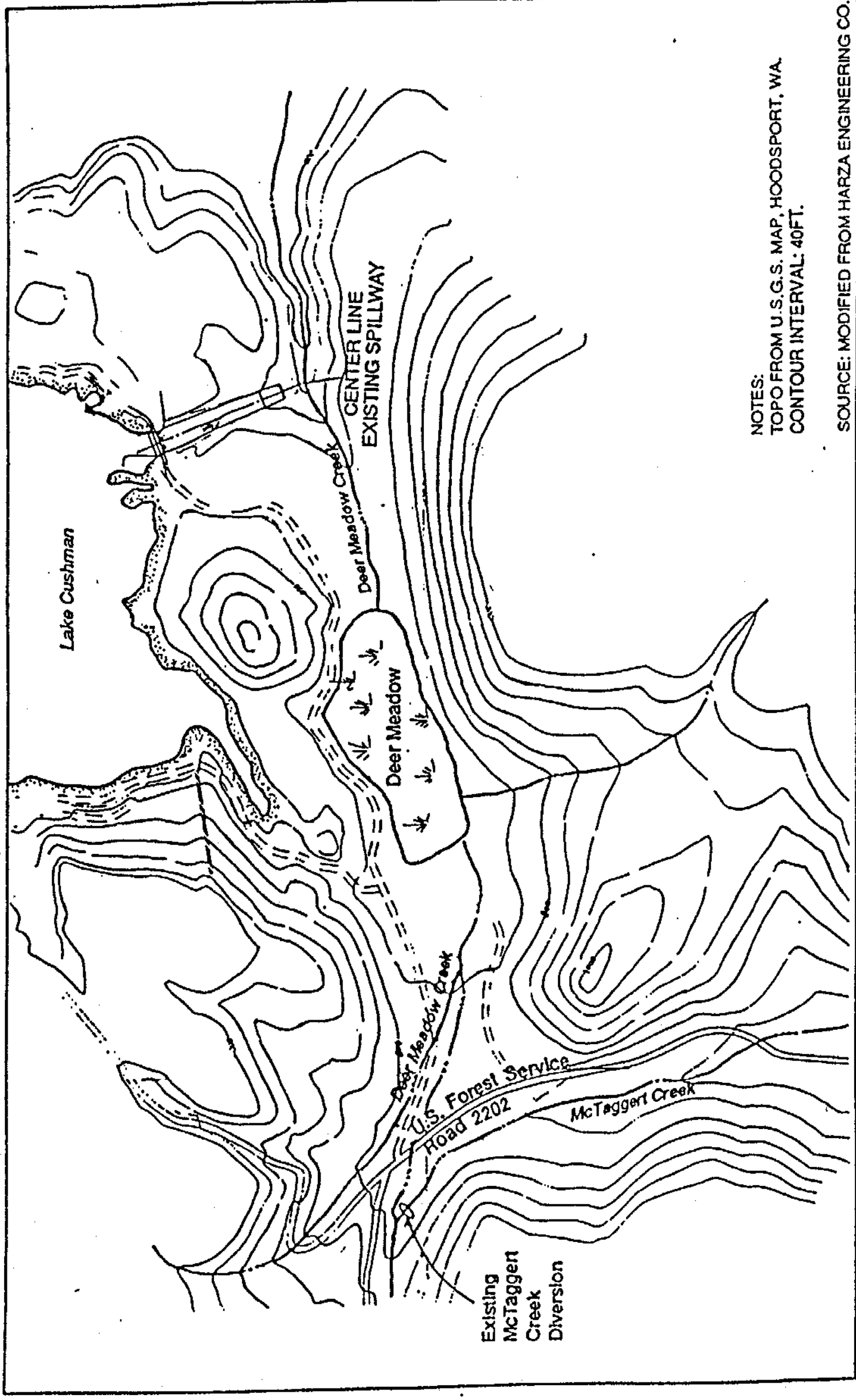

FIGURE 2

GENERAL ORIENTATION OF EXISTING SPILLWAY STRUCTURE

CUSHMAN No. 1 HYDROELECTRIC POWER PLANT, SPILLWAY

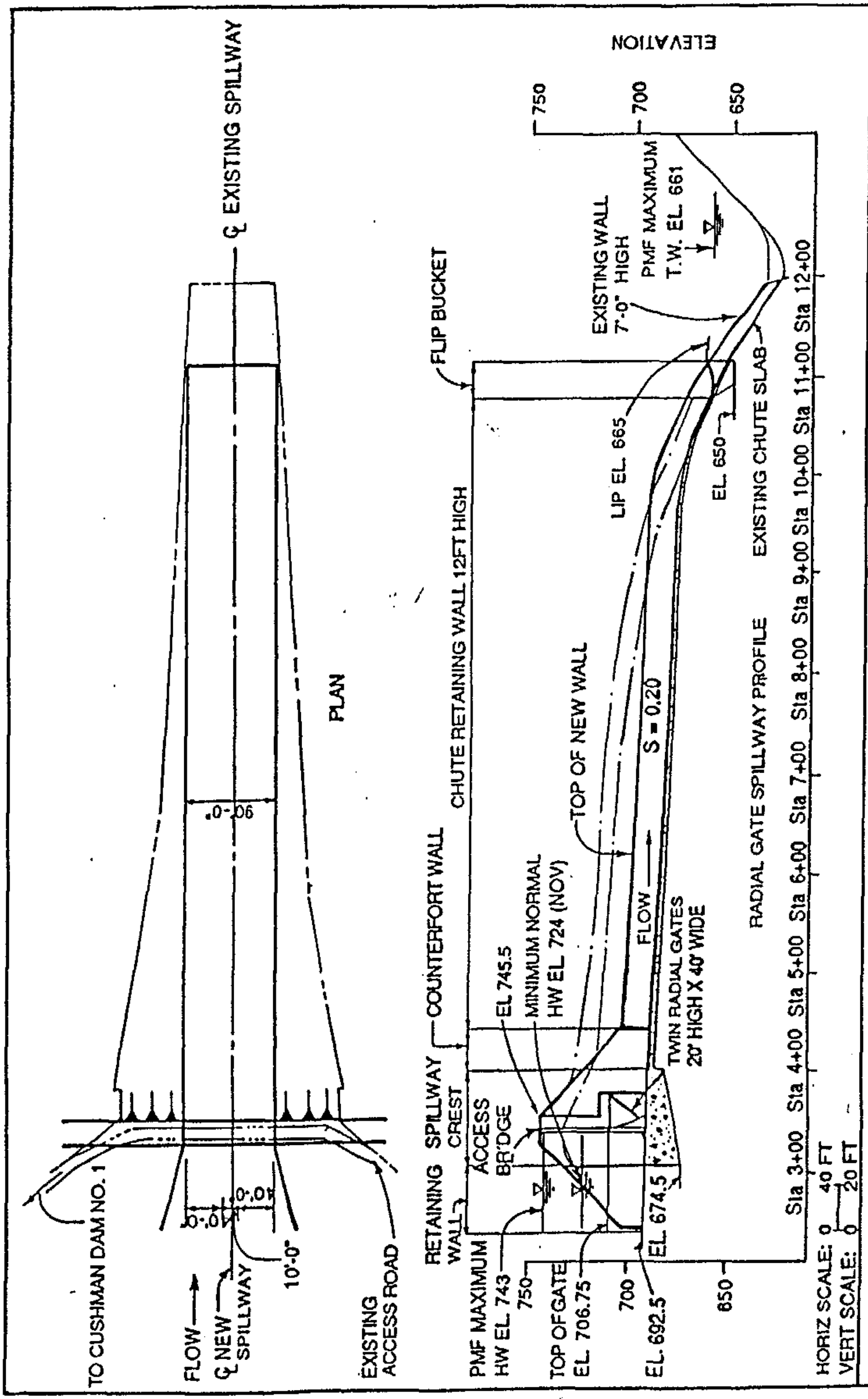

FIGURE 3

COMPARISON OF EXISTING SPILLWAY PLAN AND SECTION TO NEW ORIFICE RADIAL GATED SPILLWAY STRUCTURE

CUSHMAN No. 1 HYDROELECTRIC POWER PLANT, SPILLWAY